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Imaging the shape of atomic nuclei in high-energy nuclear collisions from STAR

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The collective properties of nuclear structure, such as radii and deformations, leave distinct signatures in the initial and consequently final stages of relativistic heavy-ion collisions. Collisions of deformed nuclear enhance the fluctuations of harmonic flow coefficients v_n and event-wise mean transverse momentum $[p_T]$, therefore offering a viable approach to establish clear correspondences between the structure of colliding nuclei and the final state observables.

We present measurements of v_n, $[p_T]$ fluctuations as well as v_n-$[p_T]$ correlations from the STAR experiment. Significant differences are observed for $[p_T]$ fluctuations and v_n-$[p_T]$ correlations between ^{197}Au+^{197}Au and ^{238}U+^{238}U collisions, which can be quantitatively explained by the large prolate deformation of ^{238}U with $\beta_{2,\mathrm{U}} \sim 0.28$ and $\gamma_{\mathrm{U}} \sim 0$. Striking differences are also observed in isobar collisions of ^{96}Ru+^{96}Ru and ^{96}Zr+^{96}Zr, where ratios of many observables show significant deviations from unity and exhibit rich patterns as a function of centrality. A comparison with hydrodynamic model simulations suggests a large quadrupole deformation in Ru nucleus with $\beta_{2,\mathrm{Ru}} \sim 0.16$ and a large octupole deformation in ^{96}Zr nucleus with $\beta_{3,\mathrm{Zr}} \sim 0.2$. The non-monotonic dependence of ratios of multiplicity distribution, v_2, and $[p_T]$ fluctuations in the mid-central collisions also requires a difference in the surface diffuseness between ^{96}Ru and ^{96}Zr in the model
calculations. Combining all these observables, we can precisely constrain the parameters associated with various nuclear deformations in isobar nuclei. Building on our pioneering demonstration of nuclear structure effects, we present a more precise quantitative extraction of the quadrupole and octupole deformation parameters in ^{96}Ru and ^{96}Zr nuclei using heavy-ion collisions.

Category

Experiment

Collaboration (if applicable)

STAR Collaboration

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